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DEVELOPMENT OF AN Al-Sn-Si POWDER METALLURGY ALLOY

by

C. F. Dixon* and H. M. Skelly**

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ABSTRACT

Powder metallurgy techniques were used to prepare an Al-Sn-Si alloy which cannot be produced by conventional means.

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INTRODUCTION

Earlier work in these laboratories has shown that Al-Si(1-7) and Al-Sn(8-10) alloys can be made by the powder metallurgy route to give materials with microstructure and properties unobtainable by present conventional methods of melting and casting. The most important characteristics of the Al-Si alloys are their excellent wear resistance and comparatively low coefficient of thermal expansion. The Al-Sn alloys are noted for their good bearing properties. Optimum properties are obtainable in both of the alloys when the microstructure is favourable, i.e., finely dispersed primary silicon and tin particles. The purpose of the work described here was to use powder metallurgy to obtain a ternary alloy of Al-Sn-Si that would combine the favourable microstructures of the Al-Sn and Al-Si alloys.

EXPERIMENTAL PROCEDURE AND RESULTS

Alloy Powder Preparation and Compositions

The alloying elements used to prepare the various powder compositions were of the following purities: Al 99.99%, Sn 99.9% and Si 99.1%. Some of the pre-alloyed powders were made with an Al-48.5% Si master alloy containing 0.26% Fe present as an impurity.

Table 1 lists the compositions and various methods of preparing the ternary alloys. For example, the first two compositions were prepared as pre-alloyed ternaries and the last composition was prepared by mixing the three elemental powders. Table 2 gives the compositions of the atomized binary alloys used to prepare some of the ternary alloys.

Consolidation of Powders

The procedures followed in attempts to consolidate the powders were based mainly on earlier work on Al-Si(1-3) and Al-Sn(8-10) alloys. The powders were first compacted isostatically at pressures of 140 or 170 MPa, the resulting billets measuring 32 mm dia by 64 mm long. The billets were then hot-pressed at temperatures of 200, 400 or 550°C under a pressure of 160 or 265 MPa. Some of the hot-pressed material was not suitable for further work, especially the billets compacted at 400 or 550°C, temperatures which caused excessive sweating of the tin constituent (melting point 232°C). The other hot-compacted powders were not sufficiently strong in this condition and, in order to consolidate them more and improve their strength, they were extruded at temperatures 130 to 400°C through a 13-mm die. In some cases the material could not be extruded due to limitations in the strength of the die or, if extruded, contained transverse cracks. Less cracking occurred when the billets were enclosed in an aluminum container 32 mm outer diameter and 3 mm wall thickness.

The results of the extrusion tests showed that the most promising composition was Al-14% Sn-15% Si (nominal) prepared from a mixture of Al-40% Sn, Al-45% Si and pure Al and hot-pressed at 200°C and 160 MPa. The diameter of the billet was reduced by grinding so that it could be jacketed in the aluminum container. The "canned" billet was then extruded at 130°C. Chemical analysis of tensile specimens machined from the extruded bar gave 13.0% Sn-13.6% Si balance Al (see Table 1). This material was chosen for examination and testing as described below.

Microstructure and Mechanical Properties

The microstructure of the Al-14% Sn-15% Si (nominal) as-extruded alloy is shown in transverse section in Fig. 1.

Two tensile specimens were machined from the rod, as extruded and after heat treating at 220°C for 1 hr. The heat treatment was carried out to determine if it would reduce the hardness of the alloy without materially lowering its strength as had been found in earlier work on Al-Sn alloys. The results are given in Table 3 together with the results of earlier work on the Al-25% Si(1) and the Al-20% Sn(8) binaries.

DISCUSSION

Figure 1 illustrates that the consolidated product is fully densified. The variously shaped coarser particles are the primary Si from the Al-45% Si portion of the powder mixture, and the fine particles are the Al-Si eutectic and Sn. Although the Si and Sn phases are comparatively small, the distribution of the Si is not optimal.

Table 3 shows that the tensile and hardness properties of the as-extruded and heat treated ternary alloy are below those quoted for the binary alloys. It is rather surprising that the hardness of the ternary alloy is below that of the binary Al-20% Sn, as one would have thought that the presence of silicon in the ternary would have made it harder. However, this trend in the hardness values is consistent with the tensile values. Heat treating of the ternary alloy raised its tensile strength slightly whereas that of the binary Al-25% Si was slightly lowered.

CONCLUSION

An Al-Sn-Si alloy, which cannot be prepared at present by conventional melting and casting, can be prepared by the powder metallurgy route. The most promising composition was Al-13% Sn-13.6% Si produced by mixing Al-40% Sn, Al-45% Si and unalloyed Al powders, followed by hot-pressing at 200°C and warm extrusion from an Al-jacketed billet.

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Table 1. Composition and Preparation of Ternary Alloys

Nominal Composition (wt %) Bal. Al		Method of Preparation	Chemical Analysis (wt %) Bal. Al	
Sn	Si		Sn	Si
10	15	Atomization	9.6	13.5
10	25	Atomization	9.7	26.2
10	17.5	50:50 mixture of atomized Al-20% Sn and atomized Al-35% Si	See Table 2 for composition of binary alloys	
14	15	Al-40% Sn, Al-45% Si and pure Al powders prepared by atomization and then mixed to give desired composition.	13.0	13.6*
			See Table 2 for composition of binary alloys.	
17	15	Al-20% Sn prepared by atomization and then mixed with Si powder to give the desired composition.	ND	ND
			See Table 2 for composition of binary alloy.	
10	15	Elemental Al, Sn and Si powders mixed to give the desired composition.	ND	ND

*analysis done on tensile specimens.

ND: not determined.

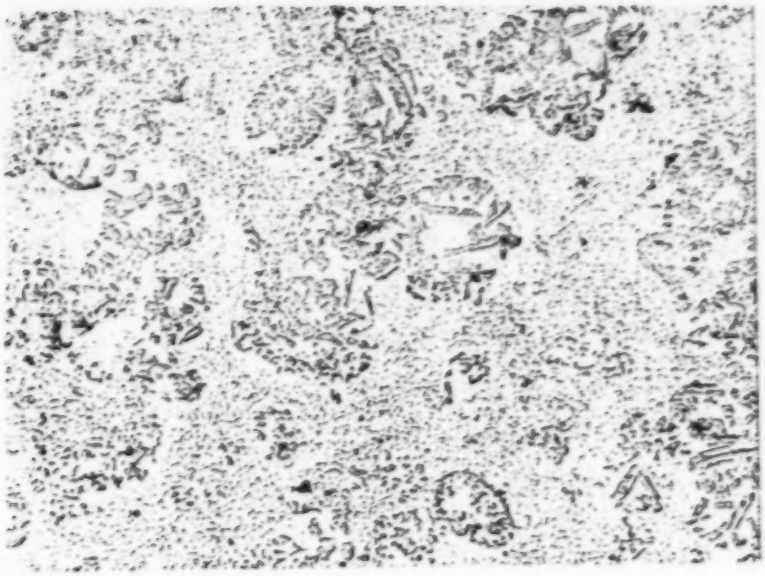
Table 2. Composition of Binary Alloys

Nominal Composition (wt %)			Chemical Analysis (wt %)		
Sn	Si	Al	Sn	Si	Al
20	--	bal	20.7	--	bal
40	--	bal	39.2	--	bal
--	35	bal	--	34.0	bal
--	45	bal	--	42.5	bal

Table 3. Mechanical Properties of Al-14% Sn-15% Si (Nominal) and of Binary Compositions.

Condition	UTS MPa			Hardness (BHN)		
	Al-14% - Sn-15% Si	Al-20% Sn	Al-25% Si	Al-14% - Sn-15% Si	Al-20% Sn	Al-25% Si
As-Extruded	79	195	229	43	55	65
Heat Treated	86*	NA	220**	40	50.5*	60.5

* 220°C for 1 hr
** 200°C for 1 hr
NA: not available



As polished 150X

Fig. 1. Microstructure of Al-14% Sn-1½ Si (nominal). Transverse section.